Serfojee Rajah 1817

EXPERIMENTS

ON THE

INSENSIBLE PERSPIRATION

OF THE

HUMAN BODY.

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OF THE

HUMAN BODY,

SHEWING ITS

AFFINITY TO RESPIRATION.

PUBLISHED ORIGINALLY IN 1779, AND NOW
REPUBLISHED WITH
ADDITIONS AND CORRECTIONS.

BY
WILLIAM CRUIKSHANK.

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ADVERTISEMENT.

THE following experiments were originally published in 1779, with some observations on the absorbent system. But as I have published two editions since that time, of the *Anatomy* of the *Absorbing Vessels* of the *Human Body*, much of the accompanying matter has been transcribed into that work, and these experiments have of course been left to themselves, and never reprinted. I have frequently thought of revising and reprinting them, but from numberless avocations have as frequently delayed it. The same reasons would still have prevented me, had not Dr. *Priestley*'s observations on these ex-

periments lately fallen into my hands, wherein he draws conclusions the reverse of mine. I have also lately met with an account of some experiments made by Mr. *Abernethy*, of St. Bartholomew's hospital, which tend to confirm my conclusions.—

Dr. *Priestley* says, "Mr. *Cruikshank's* "experiments, if they could be depended "upon, would both prove that fixed air is "composed of common air and phlogis-"ton; and that the perspiration of ani-"mal bodies, in a healthy state, has the "same effect on air that breathing it has, "viz. phlogisticating it, and making it "noxious, which is contrary to the expe-"riments of which I shall presently give "an account." And afterwards he says, "I cannot therefore but see reason to "conclude, as I did before, that it is "only respiration, and not the perspira-

"tion of the body, that injures common "air."

Mr. *Abernethy* seems to be of a contrary opinion; and mentions these experiments as follows: "Mr. *Cruikshank* entertained "the opinion, that the matter of perspi- "ration and that expelled from the lungs "in breathing, were similar in their qua- "lities. In his experiments he collected "the aqueous exhalations from the skin, "but only slightly examined the aeriform "matter. He agitated lime-water in the "air, in which his hand had been sur- "rounded, when the precipitation of the "lime shewed the existence of fixed air. "He has also observed, that a candle "burned dimly in this air."

My experiments had three objects in view.—1st, to ascertain, more accurately, the quantity of watery vapour lost in

twenty-four hours by insensible perspiration.—2dly, to ascertain, whether there was not something else in insensible perspiration beside the watery vapour, which spoiled atmospheric air.—And 3dly, to ascertain, what affinity there was between the vapour of insensible perspiration and the vapour of the lungs in expiration.

A late ingenious author has published a book entitled *Medical Extracts*; a work that would do credit to the knowledge of the first medical man in England; but to which, with a singular share of self-denial, he has not affixed his name. In mentioning these experiments he says, "These discoveries were begun by Mr. "*Cruikshank*, and confirmed by Mr. *Aber-* "*nethy*," &c. &c.

The ingenious Dr. *Ingen-Houz* has also adopted the opinion, "that air is conti-

nually issuing from the skin." I have been told that the celebrated M. *Lavoisier* has done the same, in a paper delivered to the Royal Academy of Sciences at Paris, 1792.—I feel more than common anxiety to see the opinion of that enlightened philosopher on so favourite an idea. But what chance has the world to see that, when the present rulers of France have, with a more than Gothic barbarity, murdered the author of it? What would the world have said of this country, if we had murdered Sir *Isaac Newton* — for a peculiarity of political opinion?

It would be doing Mr. *Abernethy* great injustice not to mention here his conclusions on the subject of perspiration. He says, " the least quantity of carbonic gas " (fixed air) emitted from the hand in one " hour, was *three* drachms by measure " (but he forms his calculation on two).

"If then the perspiration of all parts were "equal, seventy-seven drachm measures "of carbonic gas would be emitted, and "one-third of nitrogeneous gas (phlogis-"ticated air), in the space of an hour. "If we also suppose perspiration to be at "all times equal, nearly three gallons of "air would be thrown out of the body in "the course of one day."

As these experiments have given rise to a contrariety of opinion, I have thought it proper to reprint them as they stood in the publication of 1779. This will account for the terms of chemistry that were then in use being still retained. I have indeed added a few observations and arguments, which I have advanced every year since that period, in my anatomical lectures in Windmill-street.

I have likewise republished some ob-

servations on the skin and its pores, as introductory to the Experiments on Perspiration, in the same state they were first published in 1779—adding, in the same manner, some occasional observations.

Sept. 1, 1795. W. C.

EXPERIMENTS, &c.

REMARKS

ON THE

SKIN, AND ITS PORES.

THE skin itself was called, by the Greeks, δερμὶς, and the scarf skin, in their usual way, επὶδερμὶς. It is said to have been called δερμις παρα το δερειν, *quia exuitur quibusdam animalibus*, because it is cast by many animals once a year; the epidermis certainly is so. *Hippocrates* uses the words δερμις and επιδερμις sometimes in the same sense, as if both meant equally the skin. The cuticle is supposed indeed by some to be cast by all animals, either sensibly at one period of the year, or insensibly in scales, at all times of the year, as in man. *Lewenhoek* imagined he saw these scales by means of the microscope; and *Boerhaave* thought he proved their

existence, by wearing continually black silk gloves, which after some time he inverted, and thought he clearly saw these scales. Others say that δερμις is used for δεσμα, *quasi vinculum totius corporis*, as the membrane binding together all the parts of the body into one. The Romans called it *pellis*; evidently from *pellens*, *repelling*; as it forms vesications, and endeavours to push off matter, suddenly offending the body, as on application of scalding water, liquid caustic, alkali, or red hot iron. It is said likewise to have been called *cutis*, *ex* κυτειν *investire*, as the investing membrane of the whole body.

When carefully dissected off, and separated from all adventitious matter, in a middle sized man, it weighs about four pounds and a half.

The skin, though apparently a simple membrane, is in reality laminated, consisting of several subdivisions; the outer-

most lamen is termed with us scarf skin, or cuticle; the second lamen has no English name, is known only to anatomists, and is called *rete mucosum*; after these two are removed we come to, as is commonly thought, the surface of the skin itself. I shall make some observations on each of these.

When a blister has been applied to the skin of a Negro, if it has not been very stimulating, in twelve hours after a thin transparent grayish membrane is raised, under which we find a fluid. This membrane is the cuticle or scarf skin. When this, with the fluid, is removed, the surface under them appears black; but if the blister had been very stimulating, another membrane, in which this black colour resides, would also have been raised with the cuticle; this is *rete mucosum*, which is itself double, consisting of another gray transparent membrane, and of a black web, very much resem-

bling the *nigrum pigmentum* of the eye. When this membrane is removed, the surface of the true skin (as has hitherto been believed), comes in view, and is white, like that of a European. The *rete mucosum* gives the colour to the skin; is black in the Negro; white, brown, or yellowish, in the European. The reason why this membrane is black in the Negro, is, perhaps, that his body may be better able to defend itself against the sun's rays, and that the heat may be prevented from penetrating. The intention of a similar membrane behind the retina in the eye, appears to be not only that of absorbing the superfluous rays of light; but, like the *amalgam* behind the looking-glass, it may enable the retina to reflect the rays, in order to perfect vision. It is not very improbable that some such purpose, as enabling the cuticle to reflect the sun's rays in those warm climates, where the inhabitants originally go naked, may be the inten-

tion of nature, in giving them the black membrane. Perhaps too, the circumstance of the countenance's becoming brown, when exposed to the sun's rays in summer, in our own climate, may be a process of nature to defend herself against the access of external heat into the body.

Both cuticle and *rete mucosum* send innumerable processes into the pores of the true skin; the process of the *rete mucosum* is always within that of the cuticle, and in contact with the sides of the pore, as formed by the true skin. These processes are remarkable in the cuticle and *rete mucosum* of the elephant, some of them are almost an inch long; the cuticle, or *rete mucosum*, or a membrane very similar, having the same properties with these, appears to me to be also continued into the inside of the mouth, over the tongue, internal surface of the lungs, œsophagus, stomach,

and intestinal tube. In most of the last named parts, the cuticle, however, forms sheaths for *villi*, and not processes which line pores. On viewing the surface of the skin, even with the naked eye, we find it porous; more so in some places than in others; and the pores are also larger in some parts than others. These pores are ducts of sebaceous glands, and serve not only to transmit hairs, but in my opinion, the greatest part of the perspirable matter itself. Absorption on the skin also, in all probability, begins on the sides of these pores. They are particularly remarkable about the mouth, nose, palms of the hands, soles of the feet, on the external ear, scalp, *mons veneris*, and around the nipple in women. *Grew* thinks he was the first who observed them on the fingers; and has given a pretty just engraving of them, in the *Philosophical Transactions*. *Winslow* describes these last, and says, they are the ducts of glands. The processes which line the pores trans-

mitting hairs have been long observed, but I do not recollect that any anatomist has described these processes which line the other classes of pores. *Albinus* takes notice of the appearance, but says (if I am not mistaken), that they are the roots of hairs pulled away with the cuticle or *rete mucosum*. The processes which line the pores, would, however, from what I can collect of the opinions of the most eminent latter anatomists, be reckoned imperforated, and described as so many blind pouches, resembling the fingers of a glove, which might be pulled out of the pores entire, by long maceration of the skin in water. Of course the cuticle and *rete mucosum* would, in their opinion, be reckoned every where entire; and it must be owned, that when these membranes are separated by maceration, and viewed in the microscope, there is not the least appearance of pores. *Haller*, *Albinus* and *Meckel*, are of opinion, there are no pores in these membranes. None

of the latter anatomists have been able to discover *Lewenhoek*'s scales, of which he believed the cuticle was composed, and between whose interstices, or loose edges, the fluids passed into the body, or passed out. *Malpighi*'s and *Ruysch*'s perforations of the *rete mucosum* have been sought for with no better success. I own, that after some pains, and assisted by pretty good microscopes, I have not been able to discover perforations in the cuticle or *rete mucosum*. It is true, that by macerating the tongue of a calf in water for a considerable time, an appearance of pores may be produced in the *rete mucosum*; and it is as true, that the same appearance may be produced in the cuticle. But when the one appears perforated, the corresponding surface in the other is always not so; and where the processes are short, and easily separated from one another, neither cuticle nor *rete mucosum* appear to be perforated; and both may be demonstrated to have their own pro-

cesses. *Malpighi* first taught that the *rete mucosum* was porous. I find *Haller* of the same opinion; also asserting from *Du Hamel* that the *rete mucosum* in the feet of many birds (he particularly instances the ostrich) is perforated. I have seen those talked of perforations, and am convinced, that, as in the tongue of the calf, these are only *vaginulæ*, or sheaths for the *villi*, and cannot be demonstrated by any means to be open at top.

Though I have not found pores in either cuticle or *rete mucosum*, I believe nevertheless that they certainly exist, and for reasons which I shall give presently; but as I never could see them, I think it justice to those gentlemen who admit nothing which is not demonstrable, to say so. *Albinus* and *Meckel*, particularly the last, are disposed to believe, that whatever fluids are perspired, or what-

ever are absorbed by the skin, must equally soak through the cuticle, as the vapour of warm water does through dried leather. *Albinus* even doubts, whether the perspired fluids do not ooze through the coats of the extreme arteries themselves, as vapour, and are afterwards condensed into sweat. "*Quid ni* (says he) *penetraret, per mollia nostra, humidaque, quum calentis aquæ vapor, per durum, siccumque corium, eo modo penetret?*" Professor *Meckel* uses nearly the same language. Talking of the cuticle in the *Memoirs of the Academy of Berlin*, he says, "*Quoiqu' inaccessible aux vaisseaux, sa nature est pourtant telle, qu'il transmet le liquide, dont il est imbû, à peu près, comme pourroit le faire un cuir mince humecté.*" He also observes, that though in the palms of the hands of black-smiths, and in the soles of the feet in travellers, the cuticle consists of many layers, and is sometimes a quarter of an

inch thick, still perspiration takes place on these surfaces. Did the fine perspiring vessels reach the cuticle of the foot in the one instance, or of the hand in the other, the weight of the body, or the recoil of the hammer, he thinks must crush them to pieces.

Notwithstanding of such respectable opposition, I cannot help being persuaded, that such a process as soaking, however it may take place in dead animal substance, or vegetable, is a process too much allied to those of dead matter, to have any place in a living body. Nay, I think it may be proved, it never does take place in cuticle, even in the dead body. There are difficulties, however, on both sides. Let us examine the different facts.

The reasons which induce me to believe that there are pores organized,

connected with the extremities of the exhalent arteries, in the cuticle, and *rete muçosum*, which, however invisible in the dead separated cuticle, still exist, and are sufficiently dilated in the erected state of the extremities of the vessels of the living and perspiring skin, are the following:

When a piece of cuticle falls off from the cutis, some of the hairs go with it, and some remain with the cutis. Those hairs certainly perforated the cuticle, yet in the microscope not the least vestige of these perforations can be traced. In places where the hairs either do not exist, or where they are invisible, where, however, the pores are very numerous, as on the nose and some parts of the external ear, no perforations can be traced in the separated cuticle; though the sebaceous matter could formerly be pressed from the cavities of these pores

on the nose, in form of a small worm, of some considerable length. The processes themselves are frequently tore off, and remain with the pores of the cutis, yet no appearance of perforation is seen in the separated cuticle of any such part of the skin. I perforated pieces of cuticle with a fine needle, but these perforations were invisible in the microscope, as they would have been had I perforated the elastic gum. The pores of filtrating paper, when dry, are very manifest in the microscope; but on wetting this paper, they become invisible. The dead cuticle, and even the callous living cuticle, swell from water, though the sound parts of living cuticle do not seem to undergo any change from lying long in water. The cuticle of the palms of the hands, and of the soles of the feet, seem at least to imbibe moisture; but the cuticle on the opposite sides of the hands and feet do not appear to have undergone any

change.* If dead cuticle swells in water, its pores will inevitably become invisible. I shall, by and by, offer some reasons for making it probable at least, that the first perspiring and absorbing pores are in the processes or *vaginulæ* of the cuticle and *rete mucosum*; and that those which appear on the outside surface are secondary, resemble mucous ducts, and are common to a vast number of the primary pores. Farther, respecting the soaking of fluids through cuticle and *rete mucosum*, let it be remembered, that in many fevers the skin is for a long time parched and dry, though it looks red and feels hot; the last circumstances prove, that the

* This may be seen in the hands of a woman who washes linen; and the reason of it is, that in the palms of the hands and soles of the feet there are a great many layers of dead cuticle, which still adhere to the living by the attraction of cohesion, and which certainly absorb warm water, thicken, and are thrown into wrinkles.—When poultices are applied to these parts the same appearances are seen.

blood is determined to the skin in greater quantity than at other times, yet the fluids do not sweat out, and much less transude. Many people, notwithstanding their using exercise, even in hot weather, when the fluids must be determined to the skin, do not sweat. I have seen vesications take place from burns, from other accidents, or from the constitution; these have been left to themselves; the fluid has not appeared sensibly to evaporate; they have remained, apparently, of the same size, for eight or ten days, without the cuticles ever feeling moist. When a bit of dead skin, with its cuticle sound, and adhering, is exposed to air, it will be many weeks in drying; and were not the cuticle to separate by putrefaction, would probably never dry at all. I exposed such skin to the heat of 100°, or 120° for two days, without its appearing to have dried in the least. When cuticle happens to be rubbed off, in the

dead body, the skin dries immediately. Though the legs in *œdema* are loaded frequently with lymph, not a drop transudes through the cuticle, unless the distension has been so great as to tear it, which rarely happens. Is it probable that the same cuticle should be the most permeable and most impermeable to fluids, of any substance, at one and the same time?

But as pores are allowed to exist, why does not the fluid of vesication escape by the pores, though it may not transude? These pores, I have already said, I believed were in the processes of cuticle and *rete mucosum*, which lined the pores of the skin. If one presses his finger about the middle in hot weather, or applies a ligature, the perspirable matter will be forced out at the pores on the tops of the fingers, in round drops, at regular distances, on the spiral ridges, like the

secretion of the tarsal glands of the eyelids, after they have been immersed in spirits. In the latter case, the equal pressure of the surrounding fluid may oblige the secretion to put on the appearance of round drops. But I will not admit *Albinus's* reasoning as just, when he says, the fluid perspires, in the former instance, from every part of the skin, and is collected into drops by the equable pressure of the surrounding atmosphere. I see the drops appear at the orifices of the pores, and no where else; and their rounded form depends on their being accumulated in a round cavity, the orifice of the secondary pore. This makes it more than probable, that the perspiring pores, and, from analogy, the absorbing pores, are in the processes of the cuticle and *rete mucosum*, which line the secondary pores of the cutis; and not in that apparent external interstitial surface of the cuticle itself, placed between the

mouths of the external pores. What further confirms this idea is, that the parts most porous sweat most, and, I dare say, will be found to absorb most. The tip of the nose in warm weather, the head, the arm-pits, the soles of the feet, and palms of the hands, sweat most. Now, though I contend that there are pores in the cuticle and *rete mucosum*, still I think it possible to give a reason why the cuticle does not allow the fluid of vesication to escape, —When cuticle is detached by vesication, its processes must be compressed against its internal surface, and the pores of course will be shut. When *œdema* distends a limb, the fluids do not escape for another reason. The extreme arteries, which exhale on the skin, are, probably, compressed by the water, and the cellular membrane become turgid by exhalation, from more internal branches: and besides, sweating is a secretion which I cannot conceive consistent with the dis-

tended state of the cold skin; we have therefore no moisture, in general, from such surfaces. I have said, that I exposed skin to heat, sufficient to convert its fluids into vapour, and as vapour is allowed to be more penetrating than fluid, it should of course have dried quickly, but it did not. Now, if the *villi* are either supposed to be collapsed, or the processes compressed, one may see some reason why no moisture appeared on the skin. A state of erection, distension, and perfect freedom, may be necessary to perspiration, and easily obtained in the living body; but from the relaxation or compression of the *villi*, any process similar to perspiration may be impossible, notwithstanding the action of heat, which could not make these vessels exert a power consistent only with life. The surface of the cuticle is always covered with an unctuous, or oily secretion; this is very conspicuous in the skin of the Negro,

and makes it still more improbable, that, watery fluids soak through it: this may be one reason why it does not suffer the cutis to dry,—though I doubt it. The cuticle of the hands and feet, I allow, in the living body seem to imbibe moisture, and become softer; but it is probably, in consequence of its having less living principle than that of other parts.*

That it allows of the sweat's passing through, may be easily accounted for, though the soaking of fluids through it should be denied; for admitting that in the palms of the hands, or soles of the feet, there may be many layers of cuticle, still it is most probable, that the last formed corresponds in every respect to the first formed and intermediate layers, and that pores are opposite to pores, and connected with each other.

Besides, the *villi* appear to be length-

* See the note to page 14.

ened, as the cuticle becomes thicker; I do not mean to say, that they were not originally intended to be long on the fingers and toes, and that those parts are not proportionably more vascular, (even in the *fœtus*), than almost any other part of the skin, but it is equally probable, that the *villi* there, were originally endowed with a property of elongating themselves in proportion to the necessity, since those parts, exposed to greater friction, would of course constantly be covered with a thicker cuticle. The *villi*, I know, are supposed to be longer there, for the same reason as on the lips; that is, for the purpose of more exquisite sensation. For though I have observed, that the greater part of the *villus* consisted of blood vessels and absorbents, yet these have been supposed to be elongated on account of the nerves. I should rather believe that several purposes, besides the accompanying the nerves, might be an-

swered, by the elongating of the *villus*, and that a greater perspiration, for instance, as well as greater absorption, takes place on those surfaces. That they may be capable of furnishing a thicker and more constant succession of cuticles, is perhaps also part of the intention of nature, in forming them so large there. I have not seen any *villi* longer than those in the feet of hoofed animals, as in the horse and cow, and the corresponding pores in the hoof are equally deep. Even in the slink calf, these *villi* penetrate so deep into the hoof, that when the foot has been successfully injected, and the hoof afterwards separated by maceration, many of the tore *villi*, adhering in the pores of the hoof, have given it the appearance of being injected. On the tongues of quadrupeds, where the cuticle and *rete mucosum* are much thicker than in any part of the human body, the *villi* are also larger and longer.

If the vessels elongate as the cuticle thickens, it will be said, what is the use of the cuticle's thickening at all in the palms of the hands of hard working people, or in the soles of the feet of those who walk much? It has been presumed, that it becomes thick in these instances, in order to defend the tender vessels underneath from the effects of pressure, or violent concussions. I believe it does; though I could conceive it merely disease, yet I would not deny that a porter's hand has as delicate a sensation of touch as a lady's. Though the vessels elongate as the cuticle thickens, still they will be better supported in passing through a thick elastic medium, and better able to resist the effects of pressure, especially as the cuticle, in thickening, becomes more elastic. That the vessels of the skin may be still more defended against this pressure, is the reason we find such a quantity of cellular

substance behind it; as for example, on the heel, ball of the great toe, and buttocks.

That elasticity in parts enables them to resist violence, need not here be explained. A man may catch a cricket-ball, if it flies with ever so much force, providing his hand yields on receiving it; if the fixed hand, on the contrary, were to receive the flying ball, it might shatter every bone in it.

Dr. *Hunter* has described and delineated, in the *London Medical Essays*, white filaments passing between the cuticle and cutis. These are most remarkable in the sole of the foot, in the human subject. He suspects them to be vessels of perspiration, continued even to the cuticle. If they are vessels, it corresponds with my idea of vessels becoming larger and longer, in proportion as the cuticle becomes thicker. For these filaments are

more easily demonstrated on the heel, or ball of the great toe, where the cuticle is thickest, than any where else. We have been informed, that it has lately been discovered, that these filaments were nerves.* That the nerves never become larger, but on account of more acute sensation, or greater action in a part, appears to me a sufficient reason for rejecting the idea of larger nerves going to an insensible and nearly passive membrane. If these filaments are not vessels, from analogy to the other parts of the internal surface of cuticle, I should rather suspect they were exceeding fine processes of the cuticle and *rete mucosum*, which line the smallest pores of the true skin; and if these processes are elongated, and go inwards, as the cuticle thickens, while at the same time they serve the same purposes as the ducts of glands, it comes to the same thing, as

* Monro's Lectures, manuscript.

if more of the vessels themselves had been elongated outwards.

If these filaments are really processes of the cuticle and *rete mucosum*, then I can demonstrate three classes of processes in these membranes. The *first* line the pores, through which the hairs pass; these are the longest, and generally have the largest diameter. The *second* class are easily distinguished on the inside of the cuticle, which cover the palms of the hands or soles of the feet, or indeed on any part of cuticle; they line those pores described by *Grew*, and which *Winslow* calls the ducts of glands; they are short, compared to the former, are transparent on the sides, and have a white line in the centre, which I do not well understand; they appear, in regular order, on those parts of the cuticle which correspond to the parallel, or spiral ridges of the cutis. The abovementioned fila-

ments, perhaps constitute the *third* class, are longer than the last, and more slender than any of the former.

In order to make it probable that cuticle is a substance, which may be pervaded by fluids, though it has no pores, anatomists have adopted one of two theories, respecting its formation. The *first* is, that it consists of the callous extremities of the vessels of the skin, reduced to this state by the friction which perpetually takes place between the surface of the body, and substances coming in contact with it. *Morgagni* adopted this opinion.

The *second* is, that cuticle and *rete mucosum* were originally and still are exsudations of mucus from the ends of the vessels of the skin; that this mucus is dried and hardened by the external atmosphere into a membrane. This last

opinion has been supported by Professor *Meckel*, who observes, in confirmation of his opinion, that the black membrane, in the *rete mucosum* of the Negro, may still be dissolved in water, like mucus by maceration. I cannot persuade myself to be of either opinion. There is something else in cuticle; nor does its known properties correspond with these theories. If the friction of external substances rendered the ends of the vessels of the skin callous, whence have we cuticle so perfect, in the earliest state of the tender *fœtus*, hanging in a warm liquid, more fit for dissolving, as one would imagine, than producing callosity? If the cuticle, on the other hand, is merely concreted mucus, whence should the dead cuticle remain months in water without dissolving, or becoming putrid? the hoofs, nails, and cuticle, of animals, are supposed to be similar substances, and always come away together after macera-

tion in water; yet the hoof in the slink calf is almost an inch thick, while the cuticle is nearly the same as it is afterwards in open air.

I formerly mentioned, that the cuticle, unlike dried mucus, neither in the living nor dead body, admitted of the transuding of fluids. Dr. *Hunter* observes, in the publication already mentioned, that the fine membrane in the rind of fruit, such as lemons and oranges, has the same property, as is demonstrable from the drying and shrinking of the fruit, when this membrane is removed; whereas, if it is kept entire, the fruit may be preserved for many months.

I cannot well suppose any part of the skin of a living animal inorganic and not possessed of life. If the cuticle, though an insensible membrane, were not alive, and possessed of irritability, why should

touching it with caustic, which deprives other parts of life, and makes them drop off, have the same effect on the cuticle?

If a bit of cuticle is touched slightly with moist lunar caustic, it soon becomes black, and in a day or two drops off, shewing a new surface in every respect like the former. I do not admit that this is new cuticle, so quickly regenerated, but the cuticular surface of *rete mucosum*, which has the same appearance, and the same properties, as the cuticle.

Spirit of nitre dropt on the cuticle turns it yellow, and produces, though more slowly, the same effect as the lunar caustic does.

The substance of the teeth, like the cuticle, has been supposed to have no vessels, though it was originally deposited by vessels; and there are several

circumstances which favour this opinion; yet in attempting to saw a tooth in the living body, the patient complained of pain the moment the saw got through the enamel. If there are nerves in the bony part of a tooth, there can be no doubt of its also having vessels.*

Cartilages covering the ends of bones, in the full grown animal, have not the least vestige of vessel, that can be demonstrated; but cartilage may be absorbed as well as bone; and if in the diseased state, it is most probably vascular, it must have been so in the sound state.

Having formerly observed, that the

* Whatever I might think formerly, I am now decidedly of another opinion; the teeth are better conductors of heat and cold than any other parts of the body, and the nerves in the cavity of the tooth have also greater sensibility than the nerves of other bones; and might therefore be affected with pain in sawing the bony part of the tooth, though they themselves were not lacerated.

brain steeped for months in spirit of sea-salt, instead of being dissolved, like the muscular flesh, or like the viscera of the thorax and abdomen, becomes harder and firmer,* I wanted to see what effect concentrated acids would have upon the cuticle.

I took a piece of the cuticle of a child at birth, and divided it into three portions; each of these might be about an inch square, and were put into separate glasses, and spread out; two drachms of vitriolic acid was poured upon the first; two drachms of nitrous acid upon the second, and the same quantity of spirit of sea-salt, upon the third. After they had remained an hour in the acids, I found that they were not dissolved; I

* It not only becomes firmer, but its fibrous texture may thus easily be demonstrated. The nitrous acid, however, dissolves it entirely, and the vitriolic converts it partly into pulp.

washed them in water, and examined them particularly; that which had been put into the vitriolic acid, had, in some degree, lost its colour, and was become brownish, but was not however in the least dissolved, and the processes were still exceedingly distinct; it was not more tender to the touch, or to the endeavour to pull it asunder, than before; nor had it lost its elasticity, except in a small degree.—That which had been put into the nitrous acid, though it was not dissolved, had split into different pieces, and was more pulpy than before, like a piece of dead cuticle from the sole of the foot, macerated in warm water; it was also more tender, did not bear handling so well, but the processes and natural texture of the skin were still apparent; it had lost nearly all elasticity.—That on which the strong spirit of sea-salt had been poured, appeared to have suffered least, and had not even lost its colour

in the smallest degree; it had not lost its elasticity in any degree; nor was it apparently altered as to its texture; the minute processes themselves had undergone no change, and it could be handled with as little injury as before; these are properties in the cuticle which by no means correspond with callous vessels or concreted mucus. A very remarkable circumstance in one of these experiments was, that though the nitrous acid gives the cuticle a yellow colour, if it touches it while it adheres to the living body, it had no immediate effect of this kind upon the separated cuticle; nor did I perceive that it was yellow till next morning, after it had been many hours in water. I repeated these experiments with cuticle steeped for an hour in oil of tartar, *per deliquium*, lest any thing oily on the cuticle might have prevented the acid from getting in contact with its surfaces;—the event was the same.

My suspicions that the cuticle was organized have been still further confirmed, by some new observations I have made on skin, injected, with a view to shew the appearance of the small-pox pustule. I have now more reason to believe, that the cuticle, like some parts of the *conjunctivâ* of the eye, though it cannot be injected in the sound state, was originally vascular, and circulated the red blood. It may still have vessels carrying transparent fluids, and I would not altogether deny, that those vessels might not sometimes be again dilated so as to be capable of receiving the red blood, or our injection.— The hairs themselves, though reputed to be inorganic, like the cuticle and nails, or like the hoofs of animals, are notwithstanding said sometimes to bleed, so as to endanger life, in the disease termed *plica polonica*.

RETE MUCOSUM,

Is so called from its imagined perforations, and consequent resemblance to a net, and that it consisted only of mucus. It is that membrâne which lies immediately under the cuticle. It was not known to the ancients, and as the discovery belongs to *Malpighi*, it is sometimes called *rete Malpighi*; he first discovered it in the tongue, and afterwards transferred it to the skin; he calls it *corpus mucosum et reticulare*, and, after describing it, says, ——" *ex quo deduco non incongruam forte* " *nigredinis Æthiopum causam: certum* " *enim est ipsis cutim albam esse sicuti et* " *cuticula, unde tota nigredo a subjecto mu-* " *coso et reticulari corpore ortum trahit.*" *Riolan*, before him, thought he had discovered the cause of the black colour in the Negro, and says it was in the epidermis, and did not go so deep as the

true skin ; but the epidermis and *rete mucosum* were not then distinguished. The scarf skin, I should have said, was colourless ; the *rete mucosum*, on the contrary, is of different colours in different climates, and in different persons in different states of the body. The apparent colour of the skin entirely resides in this membrane ; it is black in the Negro, copper-coloured in the Mulatto, yellow in the Egyptian, and white in the Albino, and in the inhabitants of cold climates.— It, in the last, becomes brown in summer from the heat of the sun, and particularly in those, who at the same time are exposed to the reflection of his rays from the surface of water, as in sea voyages, and similar situations. In those where its natural colour is white, it never changes if they are always within doors when the sun is up ; and in European climates, if it has become brown during the summer heat, it becomes white again during the

winter's cold.—Even in those who live in cold climates its colour is sometimes naturally brown, or yellow. It becomes black or dark brown in the areola round the nipples of women who are somewhat advanced in pregnancy, and is then one of the surest marks of their being with child, and constantly resorted to by the medical practitioner. The colour of this membrane is transmitted from the parents to their children, and is wonderfully altered by crossing the breed; the offspring therefore of a black man by repeated intermarriages with white women, will in the fourth generation become white; and the converse of this is equally true.

Though I have not seen vessels in cuticle or *rete mucosum*, I have successfully injected a membrane between *rete mucosum* and the cutis, in the skin of those who have died of the small-pox. This

membrane I discovered in consequence of a conversation I had with Mr. *Baynham* of Virginia, at the time he shewed me some preparations of cutis, in which, he believed, he had injected *rete mucosum.* I was surprised at the appearance of vessels in his membrane running parallel to the surface of the skin, and which formed a net-work. I was not perfectly satisfied, however, even then, that it was *rete mucosum* he had injected. Mr. *Baynham* was so obliging, as to let me have his preparations home, and desired I would examine them carefully, and prosecute the subject if I pleased.

After some time spent upon this subject, I was still at a loss what to conclude of his membrane. I saw that it was certainly not *rete mucosum* which I observed had already been previously turned down, and was still adhering to the inner surface of the cuticle. This membrane was

much thicker than I conceived *rete mucosum* could be; it was exceedingly tender and pulpy. The surface from which it was removed, as well as its own internal surface, were rough; nor did the surface of the skin appear more porous than it was before. As I could not tell what to make of it, it induced me to make some similar preparations, and gave me an opportunity of discovering a very beautiful vascular membrane in the injected small-pox skin, situated in the same part with Mr. *Baynham's*, that is, between the *rete mucosum* and cutis. Mr. *Baynham's* preparations, he informed me, were made from the skin of a leg where there had been an *exostosis* of the thigh, and of consequence, a determination of more blood to the skin than usual. He had plunged the skin, after it was injected, into boiling water for a few seconds, and afterwards macerated it in cold water for several days.

I had no opportunity of making experiments upon similar skin, but I had many pieces of injected small-pox skin in spirits. Mr. *Baynham* had informed me, that he used the boiling water to thicken the membranes, and make them bear handling better. I thought the spirits would have an equally good effect. I macerated those portions of skin in putrid water for a week, during the heat of the summer; the spirits with which they had been previously impregnated made them resist the effects of this water longer. Cuticle and *rete mucosum* were already turned down; and upon the eighth or ninth day I found I could now separate a vascular membrane from the cutis, in which were also situated the injected small-pox pustules. These last consisted of circles of long floating *villi* at the circumference, but of a white uninjected substance in the centre. This central part Mr. *Hunter* had previously

said, was a slough, formed by the irritation of the variolous matter. The surface of the skin from whence this membrane was separated, was elegantly porous. The pores now appeared exceedingly more numerous, and this surface of the skin was still tough and shining. From the vast number of pores now visible I inferred, that the processes of the cuticle and *rete mucosum* must be also more numerous than we are aware of; and many of these processes must be invisible in the microscope, from their exility and delicate texture, though their corresponding pores are visible. But as the processes of the larger pores are visible to the naked eye, and as Dr. *Hunter's* white filaments are not discoverable by the microscope, after they are once tore through, the invisible processes I contend for, most probably exist, and may be the last mentioned filaments themselves. I macerated the same skin for four or five

days more, and separated another membrane, more delicate than the former, but also vascular; the former I easily preserved; the latter, attracted by the instrument which separated it, or unable to bear the agitation of the water or spirits, in which it was separated, constantly broke down; but the corresponding surface of the skin was still tough and shining; the pores were now much larger and more distinct than before, and convinced me that the appearance was natural, and that the skin had sustained no real injury in the process.

Was I to describe the different membranes which lie on the surface of the true skin, I should now say they were five, each of which I conceive is a cuticle, or an incipient cuticle.

The three first are evidently cuticles, and the two last, most probably, are

forming into cuticle, and, like the second and third, are to succeed the first, which is perpetually falling off in small portions, like scales,—the only circumstance which seems to favour *Lewenhoek's* doctrine, that the cuticle is formed of scales.

If I am still not perfectly understood respecting these five membranes, I repeat, that cuticle, commonly so called, makes the first; the *rete musosum* is double, and makes the second and third; the first vascular membrane in which the small-pox pustules are chiefly seated, makes the fourth; and the membrane, which may be separated some days after the separation of the last, by continuing the maceration, and which shews the pores still larger, makes the fifth. These two last membranes, I fancy, might easily be detected in the skins of those who die of the measles, scarlet fever, or other eruptive diseases, as well as in the small-

pox skin; for I conceive, that these eruptive diseases do not create, but demonstrate these membranes, in consequence of the great determination of blood, in these cases, to the skin.

I mean to prosecute the subject, and if any observations I may be able to make upon the skin, will throw light on the seat of eruptive diseases, or help the physician more readily to distinguish them upon their first appearance, I shall be sufficiently rewarded.

I have within these few weeks procured portions of skin, under the same circumstances, exactly, as Mr. *Baynham's*. I have been able to separate a vascular transparent membrane, smooth on both sides, and more like that which I removed from the small-pox skin after cuticle and *rete mucosum* had been turned down, than Mr. *Baynham's*; but, as it has left the

surface of the cutis rough, I am not perfectly contented even with my own preparations; they have not erazed every doubt in my mind respecting Mr. *Baynham*'s membrane; I am convinced that it is something more than the surface of the cutis itself become tender, from the previous plunging it into boiling water, and subsequent macerations in cold water, separating it into two layers; for I own, it separated of itself, without any force; but the roughness of the separated surfaces, with the tender pulpy state of the membrane, carry some suspicions of a partly *dissolved*, instead of merely *separated* lamina. Though I think that Mr. *Baynham* has separated a part of the tender surface of the cutis, with his membrane: yet as the reticulated appearance of the vessels, in the external surface of that membrane, is the same with that which I have seen in the small-pox membranes, and in skin similar to that which

he had prepared, I must believe, that one of the vascular membranes I have seen, and Mr. *Baynham's*, are, in fact, the same; and must, therefore, still consider him as the first discoverer of the *cuticula quarta*, though I do not admit that he has injected *rete mucosum*. Mr. *Baynham* will do me the justice to believe, that could I have spoken more favourably of his preparations, I would most willingly have done it; the open, unsuspicious manner with which he treated me, on my visiting him, and his frankly trusting his preparations with me, must have pre-engaged every degree of partiality in his favour on my part. From the specimens I have seen of his anatomical abilities, and from that known ardour with which he pursues his medical inquiries, I have no doubt of his becoming more deservedly eminent, than if he had actually injected *rete mucosum*, and of course done what *Ruysch* himself could not do.

THE SKIN ITSELF

Was given to man not only for feeling, in a general sense, but for perspiration, absorption, and particularly for *touch*, in which he excels all other animals, and which resides, principally, in the *tips of the fingers*. He was intended for examining, reasoning, forming a judgment, and acting accordingly;—he was fitted by this sense to examine accurately the properties of surrounding bodies, not capable of being examined by his other senses. This, among other reasons, was one why he was made erect, that the points of his fingers should not be made callous, or less sensible, *by walking on them*.

The skin of human bodies is always of a white colour, in the dead body, let the colour of the *rete mucosum* be

what it may; it is extremely full of pores, and extremely vascular; a child in full vigour comes into the world, from this circumstance, *scarlet*;—it is endowed with intense sensibility, almost all the pain, in the different operations of surgery, is past when we have divided the skin. *Haller*, speaking of the parts of the skin, over the internal condyles of each *humerus*, says they are asserted by some, to have no feeling; but immediately adds, "*ea sede mea cutis sentit.*" I do not think this assertion was necessary; I know of no part of the skin which is insensible, and the experiment of the point of a needle pushed into any part of it, will prove this to every one: some parts of the skin, no doubt, have more feeling than others, the lips for example, as *Haller* says, "*ad basia destinata.*"—The *glans clytoridis*, and the *glans penis*, with a similar intention; there, though the nerves are not so large as in

some other parts; they are longer, more numerous, and endowed with more exquisite feeling; but where the common offices of life merely are intended, the marks of superior feeling, or touch, in the skin, are the projections, above the common surface, of those packets of arteries, veins, absorbents, called *villi*; the nerves are there not only also longer, but larger, as in the points of the fingers and toes.

We are not certain that the skin is muscular, but it has properties very like those of muscle—it contracts, relaxes, and even vibrates, in some places, on certain occasions. It is extremely distensible, the skin of the *perinæum* has stretched in labour from a quarter of an inch to six inches. It is also extremely elastic, and instantly after labour has returned again to the original quarter of an inch; it is thickest on those parts intended by

nature to bear weight or pressure; of course it is thickest on the back, on the soles of the feet, and palms of the hands. It is thinner on the fore part of the body, on the insides of the arms and legs, and where its surfaces touch opposite surfaces; it is extremely thin on the lips, and allows the colour of the blood to shine through it. It is also extremely thin on the *glans penis* in men, *glans clytoridis* in women, and on the inside of the *labia pudendi*. Skin dried and dressed is extremely strong and durable, and therefore employed in making harness for horses, clothing for men, and a variety of other purposes.

I began with remarks on the skin and its pores; there are, however, a set of pores that I have not yet mentioned—the *absorbing pores*. In another work I have described the *villi* of the intestines, on which I discovered the absorbing orifices of the lacteals.

I set about discovering these absorbing orifices in the skin, but with little hopes of success. The extremities of the vessels do not there, as in the intestines, form *villi;* except on particular parts, as on the lips, tips of the fingers and toes, palms of the hands, or soles of the feet. Or if the vessels do form *villi* in other parts of the skin, these are so short, small, and crowded, as to make the surface seem smooth. Where the *villi* are long, they are still small compared with those of the intestines. The lymph is never, perhaps, absorbed with such velocity, or in such quantity, in a given time, as the chyle; or so as to make the *villus* of the skin as turgid as the intestinal one. But supposing it does, we cannot determine the time of this turgescence as in the intestines; and if we could, the lymph is still transparent, and therefore can never give that distinctness, which a white coagulated fluid produces in the *villi* of the intestines.

Leiberkuhn, we are informed, in order that he might be able to find the orifices of the lacteals, gave his patients milk to drink before death, and found it afterwards coagulated in the *villi*; but had he bathed the hands and feet in milk before death, I doubt if the absorbents of the extremities would then have taken it up, or if they had, and had taken it also in considerable quantity, still I believe it would not have coagulated, nor made the *villus* turgid, as it had not passed through these previous changes in the stomach and intestines, which convert it into chyle and dispose it to coagulate.

REMARKS

ON

INSENSIBLE PERSPIRATION.

Albinus and *Meckel* had both supposed, that the perspirable matter passed through an imperforated cuticle, in the form of vapour; the former supposed that when it appeared sensible, in the form of sweat, it was in consequence of its being condensed on the surface of the body. They compared the oozing of this vapour through the cuticle, to the steam of warm water passing through leather.

If perspiration takes place, said I, through an imperforated cuticle, so must absorption from the skin.

Their ideas were ingenious, but I could not reconcile my mind to either propo-

sition.—For sweat is frequently most copious when there is least time allowed for the condensation of the insensible perspiration; nor has it been proved that the surface of the body is then colder, or more capable of condensing this vapour, than at other times.

Though I knew that the rays of light could pass through glass, in which there are no pores, yet I could not discover any resemblance in vapour to rays of light, or that glass was, in any respect, like cuticle.

Boerhaave observed (as every body else must have done), that though the vapour of the lungs in expiration was in the summer's heat invisible, it became perfectly distinct when it was condensed by the winter's frost.

He observes, that if the hand is intro-

duced in summer into the powdered ice of an ice-house, it smokes, and gives the same appearance as the breath does in winter: he amuses himself with the idea of winter's cold being instantly produced in the midst of a summer's assembly; each individual would then appear, says he, like a heathen deity, wrapped up in his own cloud.

He says, that by thrusting the naked arm into a long narrow glass vessel, the insensible perspiration also becomes sensible, in the same way that the vapour of the lungs becomes sensible by winter's cold, or breathing on a mirror. The cold, in these instances, condenses the vapour, as cold water thrown round the worm of a still does the steam in distillation. He adds, that it was astonishing how much limpid fluid could, in this way, be collected; but says nothing of the particular quantity, nor seems to have attended to

any thing further than the insensible perspiration's becoming sensible. *Winslow* says, that he could demonstrate this insensible perspiration, by opposing his naked head to a white wall in a fine summer's day; this vapour he says, will then become visible (magnified by the sun's rays), and appear ascending like smoke.

Tachenius collected four ounces of water in bed, by previously oiling his sheets; an experiment exactly similar to that of sleeping in sheets of oiled silk—"*Olim Tachenius* (says *Haller*) *sub tela olea tincta* "*ad quatuor aquæ uncias collegit.*" The idea was ingenious, but the error here was, that the absorbents of the skin were drinking up the condensed vapour, perhaps almost as fast as it was thrown out by the vessels of perspiration.

In condensed air, where the resistance

to the ascent of the vapour of the otherwise insensible perspiration is greater, this vapour becomes extremely sensible. —" *Facillime demum* (says *Haller*) *aere* " *densiori conspicitur in cunniculis subter-* " *raneis, vidi de singulo digito, de facie,* " *deque omni nudi corporis particula, fu-* " *mum, nubemque exhalere.*"

Sanctorius, in a series of experiments, weighing himself daily for thirty years, with a view to determine the quantity of the insensible perspiration, did not take into his calculation the insensible absorption from the atmosphere; and might frequently be attributing that to checked perspiration, which belonged to insensible absorption. It was also thought, that he made the quantity of the insensible perspiration, in twenty-four hours, greater than it possibly could be. I thought I might be able to come

nearer the truth, by weighing the actual vapour of insensible perspiration, after it was condensed into a fluid.

I WISHED MUCH TO KNOW WHAT AFFINITY THERE WAS BETWEEN THE MATTER OF INSENSIBLE PERSPIRATION AND THE VAPOUR OF THE LUNGS.

The vapour of the lungs, or the breath, was said to be fixable air and water: others asserted, that it also contained phlogiston.

Having proved formerly that the calces and salts of mercury were revived into quicksilver in the body; and having constantly observed, that almost every thing we eat or drink contains phlogiston; that the vapour of the intestines was inflammable; and that there was much electric fire in the body; I thought

this latter opinion was more than probable.

I suspected that it is a particular combination of phlogiston and atmospheric air, which forms fixed air. The experiment in which the air became fixed by the burning of phosphorus of urine (the idea of which was suggested to me by the late Dr. *Keir*) seems to prove this.

The phosphorus of urine contains phlogiston, and a very fixed acid. In burning, it therefore gives over the purest phlogiston to the atmosphere. As phlogiston joined to atmospheric air produces the same effect on lime-water as fixed air, I am led to suspect, that fixed air, however obtained, is a combination of atmospheric air and phlogiston, or of something, in some respects, agreeing with phlogiston.

Though many of the properties of phlogiston are known; yet as it cannot be procured uncombined with something else, and in the simplest forms it can be procured seems frequently unwilling to leave the body to which it is united, to combine with another that may be presented, unless that body is placed with it in some uncommon situation, such as in a red heat, or exposed to a powerful acid; it is for these reasons still not perfectly known.

Before many readers can understand me, it will be necessary to premise a few observations on *fixed air* and *phlogiston.*

Calcareous earth, burnt in the fire, loses a something, which, when united with air, renders it fixed, and in consequence of this, becomes a calx, or quicklime. Before it was burnt it was insoluble in water; now that it is lime, water

dissolves a certain proportion of it. If fixed air is added to lime-water, the lime, which had combined with the water, and was invisible, now attracts the fixed air, becomes calcareous earth again, and being insoluble in water, is precipitated in fine flakes, which, for a while, are suspended in the water, and give it a milky appearance, but on standing, soon fall to the bottom, as a powder. If more fixed air is added to the water, the water acquires a power of dissolving calcareous earth; takes up the powder which it had let fall, and again becomes transparent; or if, instead of adding more fixed air to the water, some spirit of sea-salt is added, the calcareous earth effervesces with the acid, a combination is formed, and the liquor also becomes transparent. Fixed air is formed, by the fermenting of saccharine fluids into vinous; by the combination of acids and calcareous earths; the combination of acids and alkalies;

by the burning of fuel, and by the respiration of animals.

It is heavier than atmospheric air, and deposited in a vessel at rest, remains there for some time.

It will not serve for the purposes of burning or respiration ; a lighted candle introduced into it is instantly extinguished ; and an animal, if it can have no other air to breathe, dies immediately.

Fixable air concentrated, turns the infusion of purple or blue flowers red.

It also gives acidity to water, and has, for amusement, been employed instead of lemon juice, to make punch.

Metallic bodies, when exposed to a certain degree of heat, lose *phlogiston*, and are also said to become calces.

Phlogiston is that principle, which, in passing from some bodies, and combining with air, occasions, frequently, flame. Thus, a candle burning gives over its phlogiston to the air, and as effervescence is the mark of an acid and an alkali's uniting, so inflammation, or burning, is often a mark of phlogiston's combining with air.

Many bodies contain phlogiston, and are, notwithstanding incapable of inflammation. Volatile alkali, most of the metals themselves, are of this class.

The metals calcine in common air, or part with their phlogiston. Thus iron parts with it most readily, in what is commonly called rusting, but does it so slowly, that no heat or inflammation is perceived.

Metals also part with their phlogiston

in combining with acids; thus copper filings, in combining with nitrous acid, parts with its phlogiston, and forms nitrous air.

Sulphur set on fire, parts with its phlogiston to the air, and leaves the other part of its composition, the vitriolic acid, behind; so does the phosphorus of urine, leaving also its proper acid behind.

Charcoal contains it, in great quantity, and all inflammable bodies.

Phlogiston, united with air, unfits it for inflammation of inflammable bodies, or the respiration of animals; a lighted candle is extinguished on immersing it in this air; and an animal exposed to it, dies suffocated.

Phlogiston, added to substances, is said to make them lighter, and is the only

substance, which is believed to repel the centre of the earth.

Some of the most eminent chemists have doubted, however, of this last property.

With these ideas of *insensible perspiration*, *fixable air*, and *phlogiston*, I made the following experiments.

EXPERIMENT I.

About ten in the morning, the thermometer at 67° in the shade, and 71° in my apartment, my pulse beating 65 in a minute, having taken little or no exercise, and feeling perfectly well, I washed and dried my hands, and introduced my right hand into a clean empty bottle, capable of containing three pints and a half. The mouth of the bottle readily

admitted my hand; I had previously taken a dried bladder, and cutting off the bottom and upper part, had made it into a hollow cylinder; this had been wetted and drawn on the neck of the bottle, like a stocking, for some way, and was allowed to dry to the glass; the middle and opposite end were also allowed to dry as a hollow cylinder, except at that part where it was to be fixed to my wrist by a ligature. Having made this ligature, I observed, in less than a minute, that the inside of the bottle was become dim, as it would have been had one held it over the steam of warm water. In about ten minutes, small drops began to appear on the bottom and upper side of the bottle, which was held in a horizontal position, and equally covered with a thin wet piece of linen; this was moistened from time to time during the experiment, that by the cold the evaporation from it produced, the vapour in the

bottle might more readily be condensed. After keeping my hand in this situation an hour, I found I had collected a tea-spoonful of transparent and perfectly insipid fluid. This fluid I poured into the scale of a balance, which had in its opposite scale a weight, equal to the weight of a bit of dry sponge. With this sponge I absorbed the remaining fluid in the bottle, and put it into the scale with the former fluid. The fluid I had thus collected weighed thirty grains. This experiment I repeated several times, and in general with the same effect.

The greatest part of the fluid was collected by the upper side of the bottle, and the vapour seemed to have a greater tendency to ascend. This, however, might be owing to some circumstance which made the upper side of the bottle colder than the under, though I was not aware of any that could have this effect. A

quantity of lime-water, equal to the fluid collected in the bottle, weighed thirty-nine grains.

A lighted wax taper, introduced into the bottle, at the end of the hour, before the fluid was removed, and immediately on withdrawing my hand (which was done very gradually), was not extinguished, though it burnt dimly.

If my hand is to the rest of the surface of my body, as one to sixty, and if every part of that surface perspired equally with my hand, then I lost, during that hour, by insensible perspiration from the skin, three ounces and six drachms; and in twenty-four hours, at that rate, would have lost seven pounds six ounces.

EXPERIMENT II.

I repeated the foregoing experiment

some hours after walking gently in open air; at the end of the hour, the collected fluid weighed forty-eight grains. This experiment also was repeated with the same effect. From this I inferred, that the insensible perspiration was increased two-thirds nearly, during exercise; the whole surface of my skin lost in this hour six ounces; and at that rate, in twenty-four hours, would have lost twelve pounds. Hard working people, very probably, lose still more.

EXPERIMENT III.

I repeated experiment first at nine in the evening, thermometer 62°, the collected fluid weighed only twelve grains.

The insensible perspiration, then, is different under different circumstances. This quantity, however, was the smallest I ever obtained in these experiments.

The size of the body, the quantity of food taken in, the vigour with which the system is acting, the passions of the mind, external heat or cold, are circumstances which will ever occasion considerable variety in the quantity of the insensible perspiration.

EXPERIMENT IV.

I breathed for an hour into the same bottle which I had formerly used for the experiments with my hand, and under the same circumstances. I inspired fresh air, and breathed into the bottle ; as I supposed that some of the air of expiration would be returned from the bottle, and that of course all the vapour would not be condensed, I breathed more forcibly into the bottle than I would have done in ordinary respiration. The process, especially towards the end, was

exceedingly painful, and almost tempted me to give up the experiment. I believe it was the spoiled air in the bottle that affected me every time I brought my mouth to it to expire. Notwithstanding of this, I repeated this experiment next day, and with the same effect; that is, at the end of an hour I had collected a hundred and twenty-four grains of insipid transparent fluid. The fluid obtained in one of these experiments I poured into lime-water, but it produced no change on it. Notwithstanding the uneasiness I felt in breathing into the bottle, a lighted wax taper introduced into it at the end of the hour, was not extinguished.

If I lost a hundred and twenty-four grains of vapour, by respiration, in an hour, at the same rate, I should have lost six ounces, one drachm, and thirty-six grains, in twenty-four hours; which,

added to the former cutaneous exhalation, would make the whole insensible perspiration in twenty-four hours, equal to eight pounds, one drachm, and thirty-six grains; and the evaporation from the lungs, will be little more than one fifteenth of the whole.

Sanctorius,* supposing that a man took into his stomach eight pounds of liquid and solid in twenty-four hours, allowed three pounds of this to pass off by stool and urine, and the other five he laid to the account of the insensible perspiration; the evaporation from the lungs he calculated at one-sixth of the whole.

It is more than probable, that, when the body weighed heavier in *Sanctorius*'s experiments, than he expected to have found it, a circumstance which he attributed to checked perspiration, no small

* 1626.

part of this weight was to be laid to the account of increased insensible absorption from the atmosphere.

I know of no experiments which tend to ascertain the precise quantity which is absorbed from the atmosphere; nor do we know whether this absorption is constant or periodical. There are some observations which prove, that plants absorb from the atmosphere; indeed I cannot conceive, that a body endowed with the property of absorbing, should be constantly surrounded with moist and fluid air, and not absorb it.

Sanctorius was thought to have allowed too much to the effect of insensible perspiration, and the air of Italy being warmer than ours, alone made his calculation appear probable. He appears also to have allowed too little, out of eight pounds of food, for the loss by urine and the intestinal discharge. I have made the

insensible perspiration still more, and those who do not take one half of his supposed quantity into the stomach in twenty-four hours, will think the proposition absurd. These readers will please to reflect, however, that more goes into the body than they know of.*

* The quantity I have stated as thrown out by the body in insensible perspiration may appear exaggerated; I do not mean, however, that all human bodies throw out *so much*. Insensible perspiration is nature's method of getting rid of superfluous meat and drink, as well as for other purposes; but those who eat and drink little, will, in proportion, perspire less: even in those who eat and drink a great deal, the quantity seldom amounts to *Sanctorius*'s allowance—" *rara enim est ea voracitas*," says *Haller*. But there are other ways by which matter enters the body; *Galen* himself says, as I have elsewhere observed, μεταλαμβανουσὶ δε εις εαυτας του περιεχοντος ημας αερος ουκ ολιγον μοιρον.—That is, the veins in the surface of the body take in no small portion from the surrounding air.

Negroes who have been gibbeted alive, have been said to absorb as much moisture from the air, during the night, as enabled them to return it by the usual quantity of urine next day, as if they had drank their usual quantity of fluids.

EXPERIMENT V.

I breathed through lime-water in a curved glass tube, the water immediately

De Haen observed dropsical patients after they had been tapped, filled to the same size again amazingly fast, notwithstanding they were forbid liquids, and carefully watched; in consequence of this, he firmly asserts such patients absorb moisture from the atmosphere.

Haller mentions a lady who made two hundred and sixty ounces of urine daily—"*sine cibo vel potu, vel marcore.*"

The *Abbe Fontana* found that walking after a shower in moist air, for an hour or two, he returned home some ounces heavier than he went out, notwithstanding he had suffered considerable evacuation from a brisk purge, purposely taken for the experiment.

De Gorter found himself heavier in the morning by six ounces than when he went to bed, after perspiring all night under the clothes.

That thirst may be quenched by the surface of the body, or part of that surface, being immersed in water for

became turbid; and though on continuing to breathe through it, it once became less turbid, yet it never became transparent, though the breathing through it was continued for an hour. On adding some spirit of sea-salt to it, it presently became clear. When fixed air, I have said, is added to lime-water, it becomes turbid, but on adding more fixed air, the calcareous earth is dissolved, and the liquor becomes perfectly transparent. There is therefore, something else in the air of

some time, there can be no doubt; a patient of mine, by this method, who could not swallow liquids, from the stricture of the œsophagus, had his thirst quenched as if he had drank his usual quantity, and made urine in proportion. Captain *Bligh*, in his perilous voyage, mentions this curious fact, that when he and his men were almost dying from thirst, they found themselves relieved by plunging their clothes into the sea and wringing them moderately dry, and in that state putting them on. The heat of their bodies, I suppose, converted the water into vapour, which, as in the distillation of sea-water, was of course fresh, and entering the absorbing pores of the skin, had the same effect as drinking fresh water would have had.

expiration, than that something, which, added to air, makes it fixed.

EXPERIMENT VI.

I introduced into lime-water some air, in which a wax taper had been extinguished; the water instantly became turbid; no further addition of this air rendered it transparent; though it became less turbid, as in the former experiments; and spirit of sea-salt, now added, made it transparent. This air, I own, contains fixed air, but it surely contains more phlogiston. Phlogisticated air and fixed air, it must have been observed, wonderfully correspond in several of their distinguishing marks. They are both unfit for respiration and inflammation, or burning. Though they do not tally in every circumstance, may not this depend on the difference of situation, or some dif-

ference in the mode of combination? A diluted, or weaker acid, will not produce the effect of a concentrated one. The natural colour of spirit of nitre is yellow; add a little water to it, the yellow colour still remains; add a little more, it becomes green; and add much water, it becomes transparent; all the while it is still spirit of nitre and water.

EXPERIMENT VII.

I introduced into lime-water some air, in which burning phosphorus of urine had decomposed itself, and shook them together; the lime-water was instantly decomposed; no additions of this air made it transparent again; but on adding some spirit of sea-salt it became transparent. The phosphorus of urine is allowed by the chemists, to be the nearest to pure phlogiston of any substance. This expe-

riment seems to prove, that phlogiston will produce the same effect on lime-water as fixable air, and confirms the suspicion I have entertained, that phlogisticated and fixed air are, at bottom, the same.

Dr. *Priestley* found, that the electric stroke received over the surface of lime-water, occasioned a precipitation of the lime.

EXPERIMENT VIII.

I repeated experiment first, and threw the fluid so collected into lime-water; it produced no change in it. I threw some lime-water into the bottle where my hand had remained an hour; after some agitation the lime-water became faintly turbid.

EXPERIMENT IX.

I made a similar experiment to the first, with my foot instead of my hand; of course, I employed for this purpose a larger bottle. The fluid collected produced no change on the lime-water; but lime-water thrown into the bottle and agitated, became as turbid as when the air, in which the wax taper had extinguished itself, was mixed with it.

Lest the stagnating of the perspirable matter in the stocking, and its fermenting might be suspected to have generated the fixable air apparent in this experiment, I must observe, that my foot was previously washed in warm water.

This last experiment I repeated several times, and with the same success: from these I inferred, that (admitting the com-

mon theory of fixed air and phlogiston) something passed off with the vapour of insensible perspiration by the skin, which rendered air fixed. As this something, added to air, makes it heavier than atmospheric air, it should have been taken into the account of the weight of the body in *Sanctorius*'s experiments. If phlogiston passes off at the same time with the perspirable matter, along with that which, in making air fixed, makes it heavier, and if phlogiston really repels the centre of the earth, and is the principle of levity itself, then the one may counterbalance the other, and *Sanctorius*'s experiments, as far as phlogiston and fixed air are concerned, may be still pretty near the truth. If the respired vapour from the lungs, during exercise, is in the same proportion with that from the skin, under that circumstance, then the whole of the insensible perspiration will be still greater than I have made it.

EXPERIMENT X.

I introduced my hand, covered with a new shammy leather glove, into the bottle, as in experiment first, and under similar circumstances. In an hour I collected twenty-four grains of insipid transparent fluid; if the glove may be supposed to have absorbed six grains, which is very probable, then I collected nearly the same quantity as in experiment first.

EXPERIMENT XI.

I introduced my foot, with a rigidly dry boot on it, into a large bottle, and went through a process similar to experiment first. It was long before any vapour appeared on the sides of the bottle, but before the end of the hour there was some appearance of dimness, and very small drops.

The vapour of insensible perspiration, then, passes through leather; and it is very fortunate it does, since we may thus defend ourselves against the injury of the weather, and perspiration continue undisturbed. But though it pervades leather, which is a dead porous substance, yet I cannot believe that it pervades in the same manner the living cuticle. The fluids do not transude, or soak, through living membranes; nor can I believe that even vapour itself, penetrates an imperforated living cuticle. The vapour passed with difficulty through the boot. It is said, that dragoons, who constantly wear boots, have small legs. If atmospheric absorption is equally retarded on these surfaces, their growth may be prevented, like that of trees too closely planted together, and from the same cause. The pressure of the boot preventing a full exercise of the muscles, is also to be included.

The evaporation from the body, does not appear to me to be like that from dead matter. It took place within the bottle, nor was in the least interrupted though the air continued the same throughout. Were I to compare it to any thing, it would be to the steam which a torrent in falling over the brow of a rock, in its rapidity, flings off in a floating cloud, while the torrent itself holds on its way.

The *impetus* of the blood, and the relaxation of the vessels of the skin, are as certainly necessary to the passing of the insensible perspiration, as to the passing of the sweat itself.

It may, perhaps, sometimes take place like the sweat in fainting or dying animals, from relaxation of the vessels only.

If phlogiston passes off from the surface

of the body in perspiration, then living animals, and bodies on fire, are in some respects in the same situation, and are both giving off phlogiston to the atmosphere.

That the blood contains phlogiston there can be no doubt. That it burns with a blue flame when dried; that in this state it revives the calces of metals, if exposed with them to a sufficient heat; that papers dipped in the serum of the blood, when it happens to be of a white colour, dry greasy; that an oil is obtained by the distillation of the blood, are certain facts, and prove this as well as Dr. *Priestley*'s ingenious experiments.

That the blood parts with *phlogiston* in respiration I would also admit. I have a strong suspicion that it is this which converts the inspired atmospheric air partly into fixable air. Be that as it may,

I am convinced there is something more in respiration than the merely separating phlogiston from the blood.

Respiration is not only necessary to the free circulation of the blood through the lungs, but the stimulus of the atmospheric air on the lungs has a very considerable effect, in continuing, and frequently in reproducing the heart's motion.

In presence of several of my anatomical friends, I opened the windpipe of a dog, whose spinal marrow had been divided in the neck, in whom the par vagum and intercostal nerves had also been divided at the same place.* He had been

* These experiments were made for another purpose, by which I discovered the independance of the heart's motion on its nerves, as well as the reunion after division, and the regeneration after loss of substance in the nerves themselves. I wrote a paper on this subject a long time since, which the late Mr. *John Hunter*, to whose me-

apparently dead above a minute, and the heart had ceased pulsating. I introduced a large blow-pipe into the opening made in the windpipe, and began inflating the lungs. This I did, in such a way, as to imitate full and slow respiration. In about half a minute, the heart began to pulsate again; I continued my inflation of the lungs, and the heart continued to

mory and talents I am always proud to pay my tribute, presented to the Royal Society, but it was not then printed; I think Mr. *Hunter* gave me for a reason, that it controverted some of *Haller*'s opinions, who was a particular friend of Sir *John Pringle*, then President of the Royal Society. Another gentleman has lately made experiments on the same subject, and has also presented them to the Royal Society. Upon hearing these read at the Society, Mr. *Home*, with that intelligence of anatomical subjects that distinguishes his character, and the school he was bred in, remembered my experiments, though made near twenty years ago. The present President of the Royal Society, who fortunately for mankind, prefers the promulgation of science to *Haller* or any other man, on being made acquainted with this circumstance, has caused the paper on these experiments to be printed in the *Philosophical Transactions* for 1794.

beat full equable pulsations, at the rate of seventy in a minute, for a complete half hour.

The air thrown into the lungs was here phlogisticated air. It contained undoubtedly fixable air, for, by one inspiration into a large bottle containing half an ounce of lime-water, on agitating it, I could at any time render the whole turbid and white as milk. The heart's action was reproduced and kept up from the stimulus of the air on the lungs, and in consequence of keeping up their motion.

I will not affirm that it is the stimulus of bad air, which obliges the muscles of the larynx, to contract, so as to shut up the glottis, in suffocation from the vapour of burning charcoal, &c. but I believe it is nothing else. I have once or twice been nearly choked from the skin of a

currant berry, happening to get between the root of the tongue and the basis of the epiglottis. I breathed as in a fit of the asthma, and saw my face turgid with blood; this continued, till a gulp of water washed the skin away.

My ingenious friend the late Dr. *Crawford* has proved, that atmospheric air contains an astonishingly greater quantity of absolute heat, than a mixture of fixed and phlogisticated air, or the air expired from the lungs of animals. It is probable, that the heat which atmospheric air loses in the lungs on becoming fixed and phlogisticated, may give some stimulus to the system, but there is still something more I am persuaded in respiration.

I have not the smallest doubt but that *electric fluid* is also perspired from the pores of the skin—" *per poros cutis ignis* " *erumpit; et feminæ dum se pectent ignem*

"*excitant, nescio an non primum adver-*
"*tente* MERCURIO AB HELMONT" (says *Haller*), and giving his own opinion adds, —"*sed omnino perpetuum est, omnibusque* "*commune, lucem de nobis perspirare.*" It appears to me impossible that an enraged lion or cat should erect the hairs of the tail on any other principle: I have also strong suspicions, that as electric fire is now known to be the *prime conductor* of the variations in the atmosphere, that it is also the *grand conductor* of insensible perspiration.

That something else than aqueous vapour (as supposed by the ancients and by *Sanctorius*) is emitted from the pores of the skin, in insensible perspiration, there can be no doubt; independent of fixed air and phlogiston, there is an *odorous effluvia*, which, though insensible to ourselves and the bystanders, is perceptible to other animals;—this is remarkable in

the parts of generation, arm-pits, and groins. Some race of men have a peculiar smell at all times; the Jews are said to have this; the Lascars I know have it; and the feet of many Europeans have it in a horrible degree.—A dog, unchained some hours after his master had set out on a journey of a hundred miles, followed his footsteps, by the smell, and found him out the third day, in the midst of a crowd. The fox-hound knows *afar* the smell of the fox—the pointer that of the partridge, the snipe, or the pheasant; and every carnivorous animal that of its prey. This effluvia is supposed to be from the *essential oil* of the animal, for the smell is constantly the same; and as *Haller* says:— "*ex partibus indigenis necesse est oriri,*" must arise from the elemental particles of the body. There is also an *expressed oil* poured out more slowly by the perspiring vessels of the skin; this I discovered by wearing, night and day, the

same vest of the fleecy hosiery, for a month at a time, in the hottest parts of summer; at the end of the month I always found this oil, accumulated in considerable masses, on the *nap* of the internal surface of this covering, nearly in the form of black tears; these molliculæ I cut off, and exposed about a scruple of them to a red heat, in a silver spoon; the materials burnt with a white flame for a minute; it left behind a black powder, resembling in every thing the powder of charcoal. I burnt in the same manner an equal quantity of the recent nap of the fleecy hosiery, never worn; this also burnt in a white flame, but left behind only three grains of the charcoal powder. Experiments made since this Treatise went to the press, now fully convince me that oil and charcoal may be found incrustating the surface of the body, so as to make it as black as the skin of a Negro, to all appearance; this

crust burns with a white light, melts, and emits the smell of animal matter in similar circumstances, and rubbed on paper, makes it transparent; and when the inflammation is stopped, hardens on the paper, and looks like *grease;* but when completely burnt, leaves the *charcoal powder* in very considerable quantity. Nothing burns or smells which does not contain phlogiston; therefore the calces of metals do not burn, and have no smell. All this seems to prove that phlogiston is emitted from the pores of the skin.

POSTSCRIPT.

I have somewhere said in this Treatise, that calcareous earth exposed to the action of fire, in becoming quick-lime, gave over something to atmospheric air, which converted it into fixable air.

The chemists in all probability, will not allow this; but will say, that calcareous earth, in becoming quick-lime, gives over to the atmosphere fixed air already formed. I own, that vitriolic acid, and calcareous earth, *effervesce in vacuo*, and yield fixed air, without the assistance of atmospheric air: but I also believe, that atmospheric air, by receiving something from burning bodies, becomes fixed air; and I suspect, that calcareous earth, in becoming quick-lime, from the action of fire, not only yields fixed air, already

formed, and which made a part of its composition, but also gives off something, which, united to atmospheric air, makes it fixed air.

Atmospheric air passing into the lungs, in inspiration, is returned principally fixed air in expiration. I presume, that it is the same air which last entered the lungs in inspiration, which is immediately after returned in expiration, though altered as to its quality. There is one circumstance, I confess, which might be adduced, to support an opinion, that the last inspired air was detained in one set of air cells in the lungs, and that already prepared fixed air was returned from another set of cells in its stead. The circumstance I allude to is, that the lungs in the dead body (though expiration is the last action of life) always retain more air than is given out at several expirations.

It is more probable, however, that the

same air which was last inspired, is immediately expired, though changed in quality. The air in the bottle, in which I kept my foot an hour, appeared on the trial with lime-water to be fixed air, though it did not seem to have acquired any additional bulk during that period.

Should this opinion appear to be founded on wrong principles by those whose peculiar profession lead them to chemical experiments, I shall very readily give it up. Every man has a regard for his own opinions; but I hope I have still a greater regard for truth.

EXPLANATION OF THE PLATE.

Fig. 1. The spiral and other ridges of the skin, taken from an impression made by the point of my fore-finger in melting sealing-wax.

Fig. 2. The same ridges magnified to twice, or thrice, their original bulk.

Fig. 3. The pores, on similar ridges, on the point of my little finger, also magnified, as in the last figure.

Fig. 4. The different laminæ of the skin of a Negro, who died of the natural small-pox. The skin itself was injected, previously red, with liquid size, coloured with Chinese vermilion.

The uppermost stratum is the *cuticle*, which, *per se*, is colourless, but borrows a colour from the *rete mucosum* below.

The second stratum is the external lamen of *rete mucosum*, similar in every respect to the cuticle.

The third is properly *rete mucosum*, and of a deep black colour.

The fourth is the membrane, in which I discovered *the seat of the small-pox ;—it shews the elegantly radiated vascular circumference, with the central, white slough.*

The fifth membrane was too slender to draw from, at least in my preparations, which have been preserved to the present period.

The true surface of the skin now appears ; the pores are now much enlarged,

because the processes belonging to the before-mentioned membranes were all drawn out of them. Examined in the microscope they divide themselves into *pori minimi, medii, et maximi,* as *Albinus* divides the papillæ of the tongue.

Fig. 5. The pores of the skin, when cuticle, *rete mucosum,* and the membrane of the small-pox only are removed; the pores are not so large as in the last figure, but are seen placed in the angles of rhomboids, triangles, squares, and various other geometrical figures. The reason they were not seen in the lower part of the last figure was, that they disappear on removing the fifth lamina.

Fig. 6. Represents Dr. *Hunter's* filaments, and which he supposed were the vessels of perspiration themselves, passing from the surface of the true skin outwards to the cuticle.

Fig. 7. The *villi* of the skin, on the point of the fore-finger, after all the laminæ described are removed. These project above the surface of the skin, like hairs, or like the pile of velvet, and can only be made to put on the appearance they have when in action, by detaching the cuticle, and *rete mucosum*, by immersion of the skin in boiling water, previous to injection.

The *villi*, like the pores of the skin, are of different sizes, and project in some parts more than others.

The *villi*, besides other purposes, serve to conduct the immensely sensible extremities of the nerves to the under surface of the cuticle, for the purpose of touch. These *villi*, like the papillæ of the tongue, are erected when the mind thinks of touching; at all other times they are collapsed exactly as the papillæ of the tongue;

which, when hunger is appeased, are collapsed; but in a hungry person, sitting down to dinner, may always be seen erected, more projecting, more visible, and more red. Something similar may be seen in the erection of the nipple in a woman just going to give suck.

I have seen the *villi* of the intestines erected, turgid, and white, arrested by death while the chyle was absorbing; at all other times they were evidently collapsed.

As I could not make the engraver conceive their true appearance without using a magnifying glass, the *villi* are here somewhat magnified, though the fore-finger itself is of the natural size.

They resemble more the smaller papillæ of the tongue, and are therefore improperly named *villi*.

Fig. 8. The appearance of the absorbing vessels of the skin injected by the accident of mercury's running retrograde when I was pouring it into one of the absorbents of the lower extremities in the human subject.

The extremities of the absorbents, though not their orifices, were distinctly seen through the cuticle and *rete mucosum*.

FINIS.